Q: Design a dog-legged staircase for an office building. Height between floors = 3.20m
Rise = 160 mm ; Tread = 270 mm
Width of flight = width of landing = 1.25m
Liveload = 5 kN/m^2; Finish load = 0.60 kN/m^2
Use M20 concrete & Fe415 steel.

Ans:

1. Determination of Geometric parameters.

Rise = 0.16m ; Tread = 0.27m

Height b/w floor = 3.20m

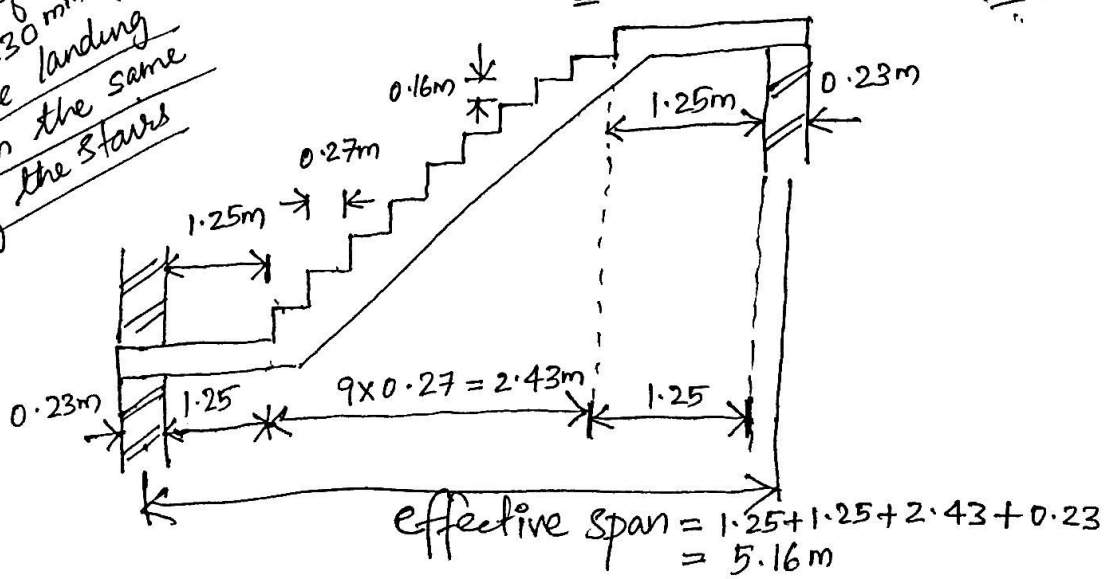
$\Rightarrow$ No. of risers = $\frac{3.20}{0.16} = \underline{\underline{20}}$

∴ Take two flights of stairs each with $\frac{20}{2}$ = 10 risers

$\Rightarrow$ No. of treads in each flight = No. of risers in each flight − 1

= 10 − 1 = $\underline{\underline{9}}$

Assume masonry wall supports of width = 230 mm
Assume that the landing slab spans in the same direction of the stairs



2. Finding depth of slab

5.16m = 5160mm

$$\frac{\text{effective span}}{\text{effective depth}} \leq 20 \times \text{Modification factor}\ (=1.25)$$

$$\Rightarrow \frac{5160}{d} \leq 20 \times 1.25$$

$$\Rightarrow d \geq \frac{5160}{20 \times 1.25} = 206\text{mm}$$

Take $d = 235$mm

Assume effective cover = 25mm

$\Rightarrow$ Overall slab depth $D = 235 + 25 = \underline{260\text{mm}}$

3. Find effective span

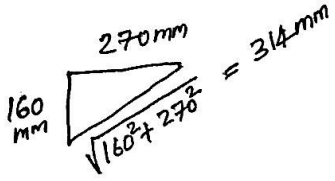
$l =$ min of { c/c dist b/w supports $= 5.16$m

clear span $+ d = 1.25 + 2.43 + 1.25 + 0.235$

$= 5.165$m

$= \underline{5.16\text{m}}$

4. Moment to be resisted (M_u):



Loads on going:

- $W_{DL,\text{waist slab}} = 25\ \text{kN/m}^3 \times 1\text{m} \times 0.26\text{m} \times \frac{314}{270} = 7.56\ \text{kN/m}$
- $w_{DL,\text{steps}} = 25\ \text{kN/m}^3 \times 1\text{m} \times \frac{0.16\text{m}}{2} = 2\ \text{kN/m}$
- $W_{LL} = 5\ \text{kN/m}^2 \times 1\text{m} = 5\ \text{kN/m}$
- $W_{FL} = 0.6\ \text{kN/m}^2 \times 1\text{m} = 0.6\ \text{kN/m}$

Total load on going $W_{going} = 15.16\ \text{kN/m}$

Factored load on going $W_{u,going} = 15.16 \times 1.5 = \underline{22.74\ \text{kN/m}}$

Load on landing:

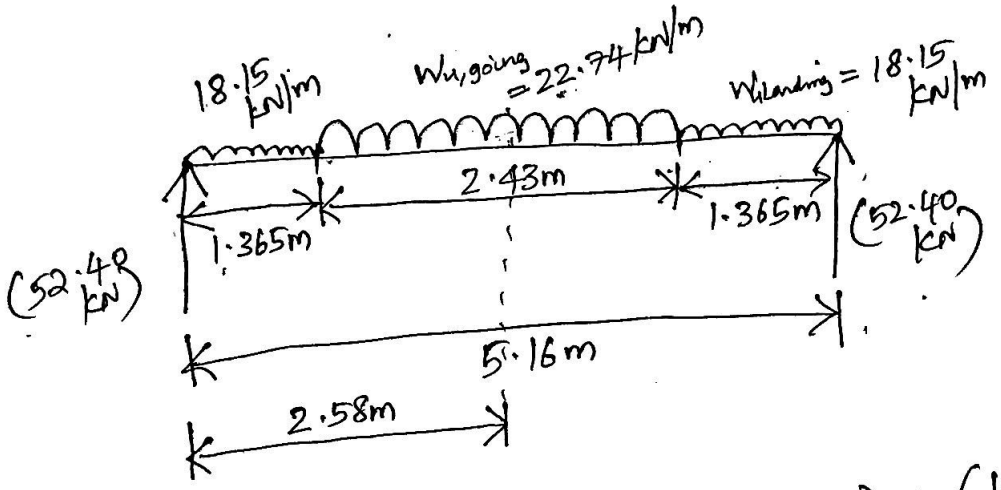
$W_{DL,landing} = 25\ kN/m^3 \times 1m \times 0.26 = 6.5\ kN/m$

$W_{LL} = 5\ kN/m^2 \times 1m = 5\ kN/m$

$W_{FL} = 0.60\ kN/m^2 \times 1m = 0.6\ kN/m$

Total load on landing $W_{landing} = 12.1\ kN/m$

Factored load on landing $W_{u,landing} = 1.5 \times 12.1 = 18.15\ kN/m$



Support reactions $= \dfrac{(18.15 \times 1.365) + (22.74 \times 2.43) + (18.15 \times 1.365)}{2}$

$= 52.40\ kN$

Max moment here is at midspan

$\therefore M_u = (52.40 \times 2.58) - \left(18.15 \times 1.365 \times \left(2.58 - \frac{1.365}{2}\right)\right) - \left(22.74 \times \frac{2.43}{2} \times \frac{2.43}{4}\right)$

$= 71.40\ kNm$

5. Finding Mulim

$$M_{ulim} = 0.36 f_{ck} b x_{umax} (d - 0.42 x_{umax})$$

$$= 0.36 \times 20 \times 1000 \times 0.48 \times 235 \left(235 - 0.42 \times \frac{0.48 \times 235}{}\right)$$

$$= 152.40 \times 10^6 \text{ Nmm}$$

$$= 152.40 \text{ kNm}$$

Since $M_u < M_{ulim} \Rightarrow$ This design is safe

6. finding depth of neutral axis:

$$M_u = 0.36 f_{ck} b x_u (d - 0.42 x_u)$$

$$\Rightarrow 71.40 \times 10^6 = 0.36 \times 20 \times 1000 x_u (235 - 0.42 x_u)$$

$$\Rightarrow 3024 x_u^2 - 1692000 x_u + 71.4 \times 10^6 = 0$$

$$\Rightarrow x_u = 46 \text{ mm}$$

$x_{umax} = 0.48 d = 0.48 \times 235 = 112.80$ mm

Since $x_u < x_{umax} \Rightarrow$ Underreinforced Section

$\therefore$ Safe

7. find main bars

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b}$$

$$\Rightarrow 46 = \frac{0.87 \times 415 A_{st}}{0.36 \times 20 \times 1000}$$

$$\Rightarrow A_{st} = 917 \text{ mm}^2$$

Assume 12mm ϕ bars,

spacing $s = 1000 \frac{A_b}{A_{st}} = 1000 \times \frac{\pi/4 \times 12^2}{917}$

$= 123 \text{ mm}$

$s \leq 3d$ or 300mm, whichever is less

$\leq 3 \times 235$ or 300 mm, "

$= 705 \text{mm}$

$\leq 300 \text{ mm}$

Provide 12mm ϕ main bars @ 120 mm c/c

8. find distributors:

$A_{s(dist)} = A_{st,min} = 0.12\%$ gross area

$= \frac{0.12}{100} \times 1000 \times 260$

$= 312 \text{ mm}^2$

Assume 8mm ϕ bars,

spacing $s = 1000 \times \frac{\pi/4 \times 8^2}{312} = 161 \text{ mm}$

$s \leq 5d$ or 450 mm, whichever is less

$\leq 5 \times 235$ or 450mm "

$= 1175 \text{mm}$

$\leq 450 \text{ mm}$

Provide 8mm ϕ distribution bars @ 150mm c/c